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Measurement of the $B^0 \to X_u^- \ell^+ \nu_\ell$ decays near the kinematic endpoint of the lepton spectrum and search for violation of isospin symmetry

The BABAR Collaboration

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Abstract

We present the first measurement of the $B^0 \to X_u^- \ell^+ \nu_\ell$ partial branching fraction in the endpoint region of the lepton momentum spectrum, above the threshold for $B \to X_c \ell \nu_\ell$ decays. The analysis is based on a sample of 383 million $\Upsilon(4S)$ decays into $B\overline{B}$ pairs collected with the BABAR detector at the PEP-II e^+e^- storage rings. We select $B^0\overline{B}^0$ events by partially reconstructing one B meson via the $\overline{B}^0 \to D^{*+}\ell^-\bar{\nu}_\ell$ decays then select $B^0 \to X_u^- \ell^+ \nu_\ell$ decays identifying a second high momentum lepton. In the momentum interval ranging from 2.3 to 2.6 GeV/c we measure the partial branching fraction $\Delta\mathcal{B}(B^0 \to X_u \ell \nu) = (1.30 \pm 0.21_{stat} \pm 0.07_{syst}) \times 10^{-4}$ where the first error is statistical and the second is systematic. By comparing this measurement with the one obtained from untagged B decays we obtain $R^{+/0} = \Delta\mathcal{B}(B^0 \to X_u \ell \nu)/\Delta\mathcal{B}(B^+ \to X_u \ell \nu) = 1.18 \pm 0.35_{stat} \pm 0.17_{syst}$. Using this measurement we extract a limit on the contributions from processes breaking isospin symmetry in charmless semileptonic B decays.

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Stanford Linear Accelerator Center, Stanford University, Stanford, CA 94309

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The *BABAR* Collaboration,

B. Aubert, M. Bona, D. Boutigny, Y. Karyotakis, J. P. Lees, V. Poireau, X. Prudent, V. Tisserand, A. Zghiche

Laboratoire de Physique des Particules, IN2P3/CNRS et Université de Savoie, F-74941 Annecy-Le-Vieux, France

J. Garra Tico, E. Grauges

Universitat de Barcelona, Facultat de Fisica, Departament ECM, E-08028 Barcelona, Spain

L. Lopez, A. Palano, M. Pappagallo

Università di Bari, Dipartimento di Fisica and INFN, I-70126 Bari, Italy

G. Eigen, B. Stugu, L. Sun

University of Bergen, Institute of Physics, N-5007 Bergen, Norway

G. S. Abrams, M. Battaglia, D. N. Brown, J. Button-Shafer, R. N. Cahn, Y. Groysman, R. G. Jacobsen, J. A. Kadyk, L. T. Kerth, Yu. G. Kolomensky, G. Kukartsev, D. Lopes Pegna, G. Lynch, L. M. Mir, T. J. Orimoto, I. L. Osipenkov, M. T. Ronan,[1] K. Tackmann, T. Tanabe, W. A. Wenzel

Lawrence Berkeley National Laboratory and University of California, Berkeley, California 94720, USA

P. del Amo Sanchez, C. M. Hawkes, A. T. Watson

University of Birmingham, Birmingham, B15 2TT, United Kingdom

H. Koch, T. Schroeder

Ruhr Universität Bochum, Institut für Experimentalphysik 1, D-44780 Bochum, Germany

D. Walker

University of Bristol, Bristol BS8 1TL, United Kingdom

D. J. Asgeirsson, T. Cuhadar-Donszelmann, B. G. Fulsom, C. Hearty, T. S. Mattison, J. A. McKenna

University of British Columbia, Vancouver, British Columbia, Canada V6T 1Z1

A. Khan, M. Saleem, L. Teodorescu

Brunel University, Uxbridge, Middlesex UB8 3PH, United Kingdom

V. E. Blinov, A. D. Bukin, V. P. Druzhinin, V. B. Golubev, A. P. Onuchin, S. I. Serednyakov, Yu. I. Skovpen, E. P. Solodov, K. Yu. Todyshev

Budker Institute of Nuclear Physics, Novosibirsk 630090, Russia

M. Bondioli, S. Curry, I. Eschrich, D. Kirkby, A. J. Lankford, P. Lund, M. Mandelkern, E. C. Martin, D. P. Stoker

University of California at Irvine, Irvine, California 92697, USA

S. Abachi, C. Buchanan

University of California at Los Angeles, Los Angeles, California 90024, USA

S. D. Foulkes, J. W. Gary, F. Liu, O. Long, B. C. Shen,[1] G. M. Vitug, L. Zhang

University of California at Riverside, Riverside, California 92521, USA

[1]Deceased

H. P. Paar, S. Rahatlou, V. Sharma

University of California at San Diego, La Jolla, California 92093, USA

J. W. Berryhill, C. Campagnari, A. Cunha, B. Dahmes, T. M. Hong, D. Kovalskyi, J. D. Richman

University of California at Santa Barbara, Santa Barbara, California 93106, USA

T. W. Beck, A. M. Eisner, C. J. Flacco, C. A. Heusch, J. Kroseberg, W. S. Lockman, T. Schalk, B. A. Schumm, A. Seiden, M. G. Wilson, L. O. Winstrom

University of California at Santa Cruz, Institute for Particle Physics, Santa Cruz, California 95064, USA

E. Chen, C. H. Cheng, F. Fang, D. G. Hitlin, I. Narsky, T. Piatenko, F. C. Porter

California Institute of Technology, Pasadena, California 91125, USA

R. Andreassen, G. Mancinelli, B. T. Meadows, K. Mishra, M. D. Sokoloff

University of Cincinnati, Cincinnati, Ohio 45221, USA

F. Blanc, P. C. Bloom, S. Chen, W. T. Ford, J. F. Hirschauer, A. Kreisel, M. Nagel, U. Nauenberg, A. Olivas, J. G. Smith, K. A. Ulmer, S. R. Wagner, J. Zhang

University of Colorado, Boulder, Colorado 80309, USA

A. M. Gabareen, A. Soffer,[2] W. H. Toki, R. J. Wilson, F. Winklmeier

Colorado State University, Fort Collins, Colorado 80523, USA

D. D. Altenburg, E. Feltresi, A. Hauke, H. Jasper, J. Merkel, A. Petzold, B. Spaan, K. Wacker

Universität Dortmund, Institut für Physik, D-44221 Dortmund, Germany

V. Klose, M. J. Kobel, H. M. Lacker, W. F. Mader, R. Nogowski, J. Schubert, K. R. Schubert, R. Schwierz, J. E. Sundermann, A. Volk

Technische Universität Dresden, Institut für Kern- und Teilchenphysik, D-01062 Dresden, Germany

D. Bernard, G. R. Bonneaud, E. Latour, V. Lombardo, Ch. Thiebaux, M. Verderi

Laboratoire Leprince-Ringuet, CNRS/IN2P3, Ecole Polytechnique, F-91128 Palaiseau, France

P. J. Clark, W. Gradl, F. Muheim, S. Playfer, A. I. Robertson, J. E. Watson, Y. Xie

University of Edinburgh, Edinburgh EH9 3JZ, United Kingdom

M. Andreotti, D. Bettoni, C. Bozzi, R. Calabrese, A. Cecchi, G. Cibinetto, P. Franchini, E. Luppi, M. Negrini, A. Petrella, L. Piemontese, E. Prencipe, V. Santoro

Università di Ferrara, Dipartimento di Fisica and INFN, I-44100 Ferrara, Italy

F. Anulli, R. Baldini-Ferroli, A. Calcaterra, R. de Sangro, G. Finocchiaro, S. Pacetti, P. Patteri, I. M. Peruzzi,[3] M. Piccolo, M. Rama, A. Zallo

Laboratori Nazionali di Frascati dell'INFN, I-00044 Frascati, Italy

A. Buzzo, R. Contri, M. Lo Vetere, M. M. Macri, M. R. Monge, S. Passaggio, C. Patrignani, E. Robutti, A. Santroni, S. Tosi

Università di Genova, Dipartimento di Fisica and INFN, I-16146 Genova, Italy

[2]Now at Tel Aviv University, Tel Aviv, 69978, Israel

[3]Also with Università di Perugia, Dipartimento di Fisica, Perugia, Italy

K. S. Chaisanguanthum, M. Morii, J. Wu
Harvard University, Cambridge, Massachusetts 02138, USA

R. S. Dubitzky, J. Marks, S. Schenk, U. Uwer
Universität Heidelberg, Physikalisches Institut, Philosophenweg 12, D-69120 Heidelberg, Germany

D. J. Bard, P. D. Dauncey, R. L. Flack, J. A. Nash, W. Panduro Vazquez, M. Tibbetts
Imperial College London, London, SW7 2AZ, United Kingdom

P. K. Behera, X. Chai, M. J. Charles, U. Mallik
University of Iowa, Iowa City, Iowa 52242, USA

J. Cochran, H. B. Crawley, L. Dong, V. Eyges, W. T. Meyer, S. Prell, E. I. Rosenberg, A. E. Rubin
Iowa State University, Ames, Iowa 50011-3160, USA

Y. Y. Gao, A. V. Gritsan, Z. J. Guo, C. K. Lae
Johns Hopkins University, Baltimore, Maryland 21218, USA

A. G. Denig, M. Fritsch, G. Schott
Universität Karlsruhe, Institut für Experimentelle Kernphysik, D-76021 Karlsruhe, Germany

N. Arnaud, J. Béquilleux, A. D'Orazio, M. Davier, G. Grosdidier, A. Höcker, V. Lepeltier, F. Le Diberder, A. M. Lutz, S. Pruvot, S. Rodier, P. Roudeau, M. H. Schune, J. Serrano, V. Sordini, A. Stocchi, L. Wang, W. F. Wang, G. Wormser
Laboratoire de l'Accélérateur Linéaire, IN2P3/CNRS et Université Paris-Sud 11, Centre Scientifique d'Orsay, B. P. 34, F-91898 ORSAY Cedex, France

D. J. Lange, D. M. Wright
Lawrence Livermore National Laboratory, Livermore, California 94550, USA

I. Bingham, J. P. Burke, C. A. Chavez, J. R. Fry, E. Gabathuler, R. Gamet, D. E. Hutchcroft, D. J. Payne, K. C. Schofield, C. Touramanis
University of Liverpool, Liverpool L69 7ZE, United Kingdom

A. J. Bevan, K. A. George, F. Di Lodovico, R. Sacco, M. Sigamani
Queen Mary, University of London, E1 4NS, United Kingdom

G. Cowan, H. U. Flaecher, D. A. Hopkins, S. Paramesvaran, F. Salvatore, A. C. Wren
University of London, Royal Holloway and Bedford New College, Egham, Surrey TW20 0EX, United Kingdom

D. N. Brown, C. L. Davis
University of Louisville, Louisville, Kentucky 40292, USA

J. Allison, N. R. Barlow, R. J. Barlow, Y. M. Chia, C. L. Edgar, G. D. Lafferty, T. J. West, J. I. Yi
University of Manchester, Manchester M13 9PL, United Kingdom

J. Anderson, C. Chen, A. Jawahery, D. A. Roberts, G. Simi, J. M. Tuggle
University of Maryland, College Park, Maryland 20742, USA

G. Blaylock, C. Dallapiccola, S. S. Hertzbach, X. Li, T. B. Moore, E. Salvati, S. Saremi

University of Massachusetts, Amherst, Massachusetts 01003, USA

R. Cowan, D. Dujmic, P. H. Fisher, K. Koeneke, G. Sciolla, M. Spitznagel, F. Taylor, R. K. Yamamoto, M. Zhao, Y. Zheng

Massachusetts Institute of Technology, Laboratory for Nuclear Science, Cambridge, Massachusetts 02139, USA

S. E. Mclachlin,[1] P. M. Patel, S. H. Robertson

McGill University, Montréal, Québec, Canada H3A 2T8

A. Lazzaro, F. Palombo

Università di Milano, Dipartimento di Fisica and INFN, I-20133 Milano, Italy

J. M. Bauer, L. Cremaldi, V. Eschenburg, R. Godang, R. Kroeger, D. A. Sanders, D. J. Summers, H. W. Zhao

University of Mississippi, University, Mississippi 38677, USA

S. Brunet, D. Côté, M. Simard, P. Taras, F. B. Viaud

Université de Montréal, Physique des Particules, Montréal, Québec, Canada H3C 3J7

H. Nicholson

Mount Holyoke College, South Hadley, Massachusetts 01075, USA

G. De Nardo, F. Fabozzi,[4] L. Lista, D. Monorchio, C. Sciacca

Università di Napoli Federico II, Dipartimento di Scienze Fisiche and INFN, I-80126, Napoli, Italy

M. A. Baak, G. Raven, H. L. Snoek

NIKHEF, National Institute for Nuclear Physics and High Energy Physics, NL-1009 DB Amsterdam, The Netherlands

C. P. Jessop, K. J. Knoepfel, J. M. LoSecco

University of Notre Dame, Notre Dame, Indiana 46556, USA

G. Benelli, L. A. Corwin, K. Honscheid, H. Kagan, R. Kass, J. P. Morris, A. M. Rahimi, J. J. Regensburger, S. J. Sekula, Q. K. Wong

Ohio State University, Columbus, Ohio 43210, USA

N. L. Blount, J. Brau, R. Frey, O. Igonkina, J. A. Kolb, M. Lu, R. Rahmat, N. B. Sinev, D. Strom, J. Strube, E. Torrence

University of Oregon, Eugene, Oregon 97403, USA

N. Gagliardi, A. Gaz, M. Margoni, M. Morandin, A. Pompili, M. Posocco, M. Rotondo, F. Simonetto, R. Stroili, C. Voci

Università di Padova, Dipartimento di Fisica and INFN, I-35131 Padova, Italy

E. Ben-Haim, H. Briand, G. Calderini, J. Chauveau, P. David, L. Del Buono, Ch. de la Vaissière, O. Hamon, Ph. Leruste, J. Malclès, J. Ocariz, A. Perez, J. Prendki

Laboratoire de Physique Nucléaire et de Hautes Energies, IN2P3/CNRS, Université Pierre et Marie Curie-Paris6, Université Denis Diderot-Paris7, F-75252 Paris, France

---

[4]Also with Università della Basilicata, Potenza, Italy

L. Gladney
University of Pennsylvania, Philadelphia, Pennsylvania 19104, USA

M. Biasini, R. Covarelli, E. Manoni
Università di Perugia, Dipartimento di Fisica and INFN, I-06100 Perugia, Italy

C. Angelini, G. Batignani, S. Bettarini, M. Carpinelli,[5] R. Cenci, A. Cervelli, F. Forti, M. A. Giorgi, A. Lusiani, G. Marchiori, M. A. Mazur, M. Morganti, N. Neri, E. Paoloni, G. Rizzo, J. J. Walsh
Università di Pisa, Dipartimento di Fisica, Scuola Normale Superiore and INFN, I-56127 Pisa, Italy

J. Biesiada, P. Elmer, Y. P. Lau, C. Lu, J. Olsen, A. J. S. Smith, A. V. Telnov
Princeton University, Princeton, New Jersey 08544, USA

E. Baracchini, F. Bellini, G. Cavoto, D. del Re, E. Di Marco, R. Faccini, F. Ferrarotto, F. Ferroni, M. Gaspero, P. D. Jackson, L. Li Gioi, M. A. Mazzoni, S. Morganti, G. Piredda, F. Polci, F. Renga, C. Voena
Università di Roma La Sapienza, Dipartimento di Fisica and INFN, I-00185 Roma, Italy

M. Ebert, T. Hartmann, H. Schröder, R. Waldi
Universität Rostock, D-18051 Rostock, Germany

T. Adye, G. Castelli, B. Franek, E. O. Olaiya, W. Roethel, F. F. Wilson
Rutherford Appleton Laboratory, Chilton, Didcot, Oxon, OX11 0QX, United Kingdom

S. Emery, M. Escalier, A. Gaidot, S. F. Ganzhur, G. Hamel de Monchenault, W. Kozanecki, G. Vasseur, Ch. Yèche, M. Zito
DSM/Dapnia, CEA/Saclay, F-91191 Gif-sur-Yvette, France

X. R. Chen, H. Liu, W. Park, M. V. Purohit, R. M. White, J. R. Wilson,
University of South Carolina, Columbia, South Carolina 29208, USA

M. T. Allen, D. Aston, R. Bartoldus, P. Bechtle, R. Claus, J. P. Coleman, M. R. Convery, J. C. Dingfelder, J. Dorfan, G. P. Dubois-Felsmann, W. Dunwoodie, R. C. Field, T. Glanzman, S. J. Gowdy, M. T. Graham, P. Grenier, C. Hast, W. R. Innes, J. Kaminski, M. H. Kelsey, H. Kim, P. Kim, M. L. Kocian, D. W. G. S. Leith, S. Li, S. Luitz, V. Luth, H. L. Lynch, D. B. MacFarlane, H. Marsiske, R. Messner, D. R. Muller, S. Nelson, C. P. O'Grady, I. Ofte, A. Perazzo, M. Perl, T. Pulliam, B. N. Ratcliff, A. Roodman, A. A. Salnikov, R. H. Schindler, J. Schwiening, A. Snyder, D. Su, S. Sun, M. K. Sullivan, K. Suzuki, S. K. Swain, J. M. Thompson, J. Va'vra, A. P. Wagner, M. Weaver, W. J. Wisniewski, M. Wittgen, D. H. Wright, A. K. Yarritu, K. Yi, C. C. Young, V. Ziegler
Stanford Linear Accelerator Center, Stanford, California 94309, USA

P. R. Burchat, A. J. Edwards, S. A. Majewski, T. S. Miyashita, B. A. Petersen, L. Wilden
Stanford University, Stanford, California 94305-4060, USA

S. Ahmed, M. S. Alam, R. Bula, J. A. Ernst, V. Jain, B. Pan, M. A. Saeed, F. R. Wappler, S. B. Zain
State University of New York, Albany, New York 12222, USA

M. Krishnamurthy, S. M. Spanier, B. J. Wogsland
University of Tennessee, Knoxville, Tennessee 37996, USA

[5]Also with Universita' di Sassari, Sassari, Italy

R. Eckmann, J. L. Ritchie, A. M. Ruland, C. J. Schilling, R. F. Schwitters
University of Texas at Austin, Austin, Texas 78712, USA

J. M. Izen, X. C. Lou, S. Ye
University of Texas at Dallas, Richardson, Texas 75083, USA

F. Bianchi, F. Gallo, D. Gamba, M. Pelliccioni
Università di Torino, Dipartimento di Fisica Sperimentale and INFN, I-10125 Torino, Italy

M. Bomben, L. Bosisio, C. Cartaro, F. Cossutti, G. Della Ricca, L. Lanceri, L. Vitale
Università di Trieste, Dipartimento di Fisica and INFN, I-34127 Trieste, Italy

V. Azzolini, N. Lopez-March, F. Martinez-Vidal,[6] D. A. Milanes, A. Oyanguren
IFIC, Universitat de Valencia-CSIC, E-46071 Valencia, Spain

J. Albert, Sw. Banerjee, B. Bhuyan, K. Hamano, R. Kowalewski, I. M. Nugent, J. M. Roney, R. J. Sobie
University of Victoria, Victoria, British Columbia, Canada V8W 3P6

P. F. Harrison, J. Ilic, T. E. Latham, G. B. Mohanty
Department of Physics, University of Warwick, Coventry CV4 7AL, United Kingdom

H. R. Band, X. Chen, S. Dasu, K. T. Flood, J. J. Hollar, P. E. Kutter, Y. Pan, M. Pierini, R. Prepost, S. L. Wu
University of Wisconsin, Madison, Wisconsin 53706, USA

H. Neal
Yale University, New Haven, Connecticut 06511, USA

[6]Also with Universitat de Barcelona, Facultat de Fisica, Departament ECM, E-08028 Barcelona, Spain

1 INTRODUCTION

The precise determination of $|V_{ub}|$, the magnitude of the Cabibbo-Kobayashi-Maskawa [1] matrix element, with well-understood uncertainties is one of the prime goals of heavy flavor physics. Recently, significant progress has been made with larger data samples available at the B-Factories and a variety of improved experimental techniques [2]. Advances in QCD calculations of leading and subleading contributions to partial decay rates in restricted regions of phase space, and the measurements of the b-quark mass and non-perturbative parameters from inclusive spectra in $B \to X_s \gamma$ and $B \to X_c \ell \nu$ [7] have resulted in much reduced errors on $|V_{ub}|$. One of the effects that is not included in current calculations of the partial decay rate, is weak annihilation (WA) [3], which is expected to contribute at the level of a few percent [4, 5, 6, 7]. Simply speaking, WA refers to the annihilation of the $b-\overline{u}$ pair to a virtual W boson, and results in an enhancement of the decay rate near the endpoint of the q^2 spectrum. Here q^2 refers to the mass squared of the virtual W.

Experimentally, WA should be observable as a violation of isospin invariance, i.e. difference in the partial decay rates of $B^0 \to X_u^- \ell^+ \nu$ and $B^+ \to X_u^0 \ell^+ \nu$, at high q^2, since it occurs only for charged B mesons.

In this paper, we report a first measurement of the partial branching fraction for inclusive $B^0 \to X_u^- \ell^+ \nu$ decays [8] above 2.3 GeV/c of the charged lepton momentum. $B^0\overline{B}^0$ events produced at the $\Upsilon(4S)$ resonance are tagged by the partially reconstructed $\overline{B}^0 \to D^{*+} \ell^- \bar{\nu}_\ell$ decays. We identify the charmless semileptonic decay of the second B meson in the event and compare its partial decay rate with the partial rate for the sum of charged and neutral B mesons previously published [8], and extract the difference in these partial decay rates between B^+ and B^0 mesons.

2 THE *BABAR* DETECTOR AND DATASET

We use a data sample of 383 million $B\bar{B}$ pairs produced by the PEP-II asymmetric-energy e^+e^- collider and collected by the *BABAR* experiment [9] at the Stanford Linear Accelerator Center on the $\Upsilon(4S)$ resonance (on-resonance data), and about 36 fb^{-1} collected 40 MeV below the resonance (off-resonance data) to study non-$B\overline{B}$ (continuum) background events. A detailed description of the *BABAR* detector, of charged and neutral particle reconstruction and identification is provided elsewhere [9]. Trajectories of charged particles are measured with two tracking systems inside a 1.5-Tesla superconducting solenoid, a 5-layer double-sided silicon vertex tracker and a 40-layer drift chamber (DCH). Both tracking systems are equipped to measure energy loss due to specific ionization (dE/dx), which is used to discriminate pions, kaons, electrons, muons, and protons. Additional particle identification is provided by Cerenkov radiation, which is generated in an array of silica bars surrounding the DCH and is detected by an array of phototubes. The energy from electromagnetic showers in a CsI(Tl) crystal calorimeter is measured and used to reconstruct photons and to identify electrons. The iron flux return of the solenoid is instrumented with layers of resistive-plate chambers and limited-streamer tubes, which are used to identify muons. For background and efficiency corrections that cannot be measured from data, we use a full simulation of the detector based on GEANT4 [10]. The equivalent luminosity of the simulated $\Upsilon(4S) \to B\overline{B}$ event sample

[7] We indicate with X the hadronic system in semileptonic B decays. We use the notation X_u and X_c when referring, respectively, to charmless and charmed hadronic system.

[8] By charged lepton, ℓ we mean here only electron or muon. Charge conjugated states are always implied throughout this paper. Momentum and energy are computed in the $\Upsilon(4S)$ frame, unless the lab frame is explicitly mentioned.

amounts to about 960 fb^{-1}.

3 EVENT SELECTION

The analysis proceeds in two steps. First $B\overline{B}$ events are tagged searching for $\overline{B}^0 \to D^{*+}\ell^-\bar{\nu}_\ell$ events identified with a partial reconstruction technique [11] described below. Second, in the tagged sample we identify $B^0 \to X_u \ell^+ \nu$ decays searching for events with an additional high momentum lepton.

We select $\overline{B}^0 \to D^{*+}\ell^-\bar{\nu}_\ell$ events on the tag side, by partial reconstruction of the decay $D^{*+} \to \pi_s D^0$ using only the charged lepton from the $\overline{B}^0$ decay and the soft pion (π_s) from the D^{*+} decay. The D^0 decay is not reconstructed, resulting in a high selection efficiency. To suppress leptons from several background sources, the tag lepton must have a momentum in the range $1.4 < P_{\ell,tag} < 2.3$ GeV/c. The momenta of the π_s candidates must lie in the range $60 < p_{\pi_s} < 200\,\mathrm{MeV}/c$. To reduce continuum background, we select events with at least 5 charged tracks with a ratio of the second to the zeroth order Fox-Wolfram [12] moment $R_2 < 0.5$. We construct a likelihood discriminator $\mathcal{L}$, using as input the lepton momentum $P_{\ell,tag}$, the π_s momentum p_π and the probability that ℓ_{tag} and the π_s originate from a common vertex, constrained to the beam-spot in the plane transverse to the beam direction. We apply a cut on this discriminator to suppress background and, in case of multiple $\ell_{tag} - \pi_s$ candidates, to select the candidate with the highest likelihood value of $\mathcal{L}$.

We approximate the mass of the undetected neutrino

$$M^2_{\nu,tag} = \left(\frac{\sqrt{s}}{2} - E_{D^{*+}} - E_{\ell^-}\right)^2 - (\mathbf{P}_{D^{*+}} + \mathbf{P}_{\ell^-})^2, \qquad (1)$$

where $\sqrt{s}/2$ is the beam energy in the e^+e^- center-of-mass frame, E_{ℓ^-} and $\mathbf{P}_{\ell^-}$ are the energy and momentum vector of the lepton. The energy $E_{D^{*+}}$ and the momentum $\mathbf{P}_{D^{*+}}$ of the D^{*+} meson are estimated as a linear function of the energy of the slow pion π_s, with parameters obtained from the simulation. We approximate the direction of the D^{*+} to be that of the π_s.

The distribution of $M^2_{\nu,tag}$ peaks at zero for $B^0 \to D^*\ell\bar{\nu}_\ell X$ events, while it extends over a wider range for all other events (see Fig. 1). We define a signal region, $-3 < M^2_{\nu,tag} < 2$ GeV$^2/c^4$, which contains 98% of the signal events, and a side band region, $-10 < M^2_{\nu,tag} < -4$ GeV$^2/c^4$, which is populated mostly by background events.

Events that contribute to the peak at zero in the $M^2_{\nu,tag}$ distribution, are mainly due to the following processes: (a) $\overline{B}^0 \to D^{*+}\ell^-\bar{\nu}_\ell$ decays (primary), (b) $\overline{B}^0 \to D^{*+}\overline{D}, \overline{D} \to \ell^- X$, $\overline{B}^0 \to D^{*+}\tau^-\bar{\nu}_\ell$, $\tau^- \to \ell^- X$ (cascade), (c) $\overline{B}^0 \to D^{*+}h^-$ (fake), where the hadron ($h = \pi, K$) is erroneously identified as a lepton, (in most of the cases a muon), and (d) $\overline{B} \to D^{*+}(n\pi)\ell^-\bar{\nu}_\ell$, (with the number of π: $n \geq 1$), where the $D^{*+}(n\pi)$ may or may not originate from an excited charm state (D^{**}). Source (a) accounts for about 90% of the events that contribute to the peak in the $M^2_{\nu,tag}$ distribution, while source (d) contains a sizeable contribution from B^+ which constitutes the peaking background on the tag side, and sources (b) and (c) account for few percent of the peak. Non-peaking background is due to remaining $B\overline{B}$ decays and due to continuum processes.

The continuum background is taken from the off-resonance data sample scaled by the luminosity ratio of the on-resonance and off-resonance data sets. The $B\overline{B}$ background is taken from simulation. We validate the simulation of the non-peaking background by comparing on-resonance data with the sum of $B\overline{B}$ Monte Carlo simulation and off-resonance data in a wrong-charge sample (WC), which is selected by requiring that the lepton and the soft pion have equal electrical charge [13]. We determine $\mathcal{N}_{B^0}$, the number of tagged $\overline{B}^0$ in our sample by a χ^2 fit to the $M^2_{\nu,tag}$ distribution in

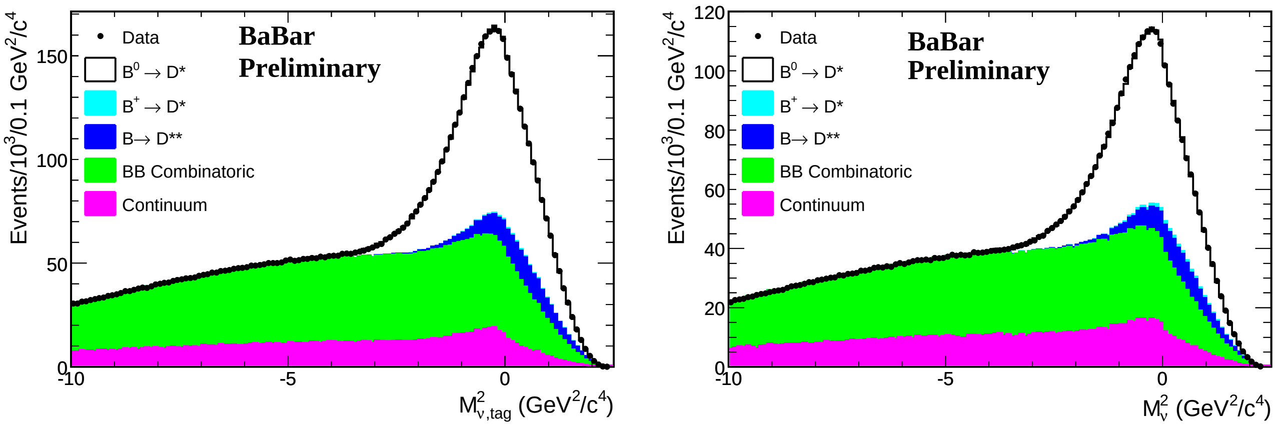

Figure 1: The $M^2_{\nu,tag}$ distribution of the tag sample summed over all the lepton momenta and all data-taking periods, compared to the results of the fit shown as the sum of various contributions (stacked histograms); $\ell_{tag} = e$ (left) and $\ell_{tag} = \mu$ (right).

the interval $-10.0 < M^2_{\nu,tag} < 2.5$ GeV$^2/c^4$. To reduce the sensitivity of the result to the details of the simulation, such as the description of the π_s reconstruction efficiency and the modeling of the $B \to D^*\ell\nu$ and $B \to D^{**}\ell\nu$ decays, we perform the fit in ten bins of the momentum, $P_{\ell,tag}$, of the tagged lepton. The free parameters in the fit are the number of events from primary decays, from $B \to D^{**}$ decays, and from combinatorial $B\overline{B}$ background. The $M^2_{\nu,tag}$ shapes of these samples are taken from simulation. The continuum contribution is taken from off-resonance data and fixed and the fractions of events from sources (b) and (c) are fixed to the prediction from the simulation. We divide the data into ten different subsamples, separating by lepton kind and different data-taking periods. We perform the fit for each of these subsamples. Figure 1 shows the result of the fit.

According to isospin symmetry, the relative contributions of B^- and $\overline{B}^0$ to the D^{**} component should be 2/3 and 1/3, respectively. The isospin symmetry hypothesis is validated with a precision of about 10% [14], so we assign (66±7)% of the D^{**} events to the peaking B^- background and the rest to the $\overline{B}^0$ events. The fit shows that decays with a D^{**} constitute 8% of the peaking sample. We assign a systematic uncertainty of 0.8% to the fitted number of $\overline{B}^0$ events due to isospin symmetry.

The total number of tagged B^0 decays with $M^2_{\nu,tag} > -10.0$ GeV$^2/c^4$ is $\mathcal{N}_{B^0} = (3606.4 \pm 9.2_{stat} \pm 47.1_{syst}) \times 10^3$, where the systematic error includes uncertainties on the $M^2_{\nu,tag}$ shapes predicted by the simulation for each sample, on the fraction of events from samples (b) and (c), and on the composition of the D^{**}.

To enrich charmless semileptonic decays, we select tagged events with an additional identified lepton (electron or muon) with momentum $P_\ell > 2.2\,\mathrm{GeV}/c$. In this momentum range the identification efficiency is about 0.95 for electrons and 0.60 for muons.

Continuum production is the largest source of background at high lepton momentum ($P_\ell > 2.4\,\mathrm{GeV}/c$). We therefore apply some further selection criteria, which depend on the flavor of the two charged leptons (ee, $\mu\mu$, or $e\mu$). These criteria are optimized using off-resonance events and on-resonance events well above the kinematic limit for $B \to X_u\ell\nu_\ell$ decays, $P_\ell > 2.8$ GeV/c.

We reject events if the angle between the charged leptons is close to zero or π, or if the invariant mass of these two leptons is less than 0.5 GeV/c^2. To reduce the number of radiative Bhabha events, we ask for at least six charged tracks in ee events. We require the aplanarity A of the event, defined

in Ref.[15], to exceed 0.002.

The missing momentum p_{miss} is computed in the $\Upsilon(4S)$ frame, as the vector sum of the momenta of all charged tracks and calorimeter showers. We select events with $\mathbf{p}_{miss}$ pointing inside the detector acceptance and in the range $0.5 < |\mathbf{p}_{miss}| < 3.8\,\mathrm{GeV}/c$. These criteria reduce the continuum background by a factor of 7.7 (3.5), and retain 74% (83%) of the e (μ) signal events.

We reduce $B \to J/\psi, \psi' \to \ell\ell$ background by rejecting $e^{\pm}e^{\mp}_{tag}$ or $\mu^{\pm}\mu^{\mp}_{tag}$ pairs if their invariant mass is consistent with the J/ψ or ψ' mass. We also pair $\mu^{\pm}$ with tracks of opposite charge and reject them if the invariant mass of the pair is consistent with a J/ψ or ψ'.

We reduce background from $B \to X_c\ell\nu_\ell$ decays by rejecting events with two or more kaons (either $K^{\pm}$ and K_s). We also reject events if the charged lepton combined with a low momentum π of opposite charge forms a second D^{*-}.

In the interval $2.3 < P_\ell < 2.6$ GeV/c, the selection criteria retain 25 (20)% of the $B \to X_c\ell\nu_\ell$ background, and 70% (65%) of the $e(\mu)$ signal.

4 SIGNAL YIELDS

We group correctly tagged $\overline{B}^0$ decays on the basis of the associated lepton:

1. **Signal**, ℓ comes from $B^0 \to X_u\ell^+\nu_\ell$ decay.
2. $\overline{B}^0$ **background**, where ℓ comes from either:
   (a) $B^0 \to X_c\ell\nu_\ell$ decays (c-background) ;
   (b) $B^0 \to DhX$ with the hadron h misidentified as a lepton (fake) ;
   (c) secondary leptons from $B^0 \to D \to \ell X$, $B^0 \to \tau \to \ell X$ and $B^0 \to \psi \to \ell X$ decays (cascade)

We determine the number of signal events as a subsample of the tagged events with an extended binned maximum likelihood fit to the $M^2_{\nu,tag}$ distribution, using a fit method that properly accounts for the statistical uncertainties of both the data and the simulation [16]. We perform three fits for three partially overlapping intervals of ΔP_ℓ: $2.2-2.6$ GeV/c, $2.3-2.6$ GeV/c, and $2.4-2.6$ GeV/c.

We fit the $M^2_{\nu,tag}$ data distribution with the sum of three distributions: combinatoric background (sum of continuum and non-peaking $B\overline{B}$), peaking $B\overline{B}$ background, and $B^0 \to X_u\ell^+\nu$ signal. The peaking $B\overline{B}$ background is mostly due to $B \to X_c\ell\nu$ decays. Its amount is fixed to the Monte Carlo prediction, adjusted to the latest measurements of semileptonic branching fractions and form-factor parameters. The $M^2_{\nu,tag}$ shape for combinatorial background is taken from the wrong-charge data control sample.

The results of the three fits are detailed in Table 1. Figure 2 shows the comparison between the fit results and the data in the intervals $\Delta P_\ell =$ 2.2-2.6 GeV/c (top) and 2.3-2.6 GeV/c (middle) and 2.4-2.6 GeV/c (bottom), separately for e and μ.

The inclusive partial branching fraction, for a given interval ΔP_ℓ in the lepton momentum, is calculated according to the following formula:

$$\Delta\mathcal{B}(\Delta P_\ell) = \frac{\mathcal{N}_u}{\varepsilon(\Delta P_\ell)\cdot\mathcal{N}_{\overline{B}^0}}[1+\delta_{rad}(\Delta P_\ell)], \tag{2}$$

where $\mathcal{N}_u$ is the number of fitted $B^0 \to X_u\ell\nu$ events, $\varepsilon(\Delta P_\ell)$ is the average efficiency to select $B^0 \to X_u\ell^+\bar{\nu}_\ell$ decays in the momentum range considered, $\mathcal{N}_{\overline{B}^0}$ is the total number of tagged $\overline{B}^0$,

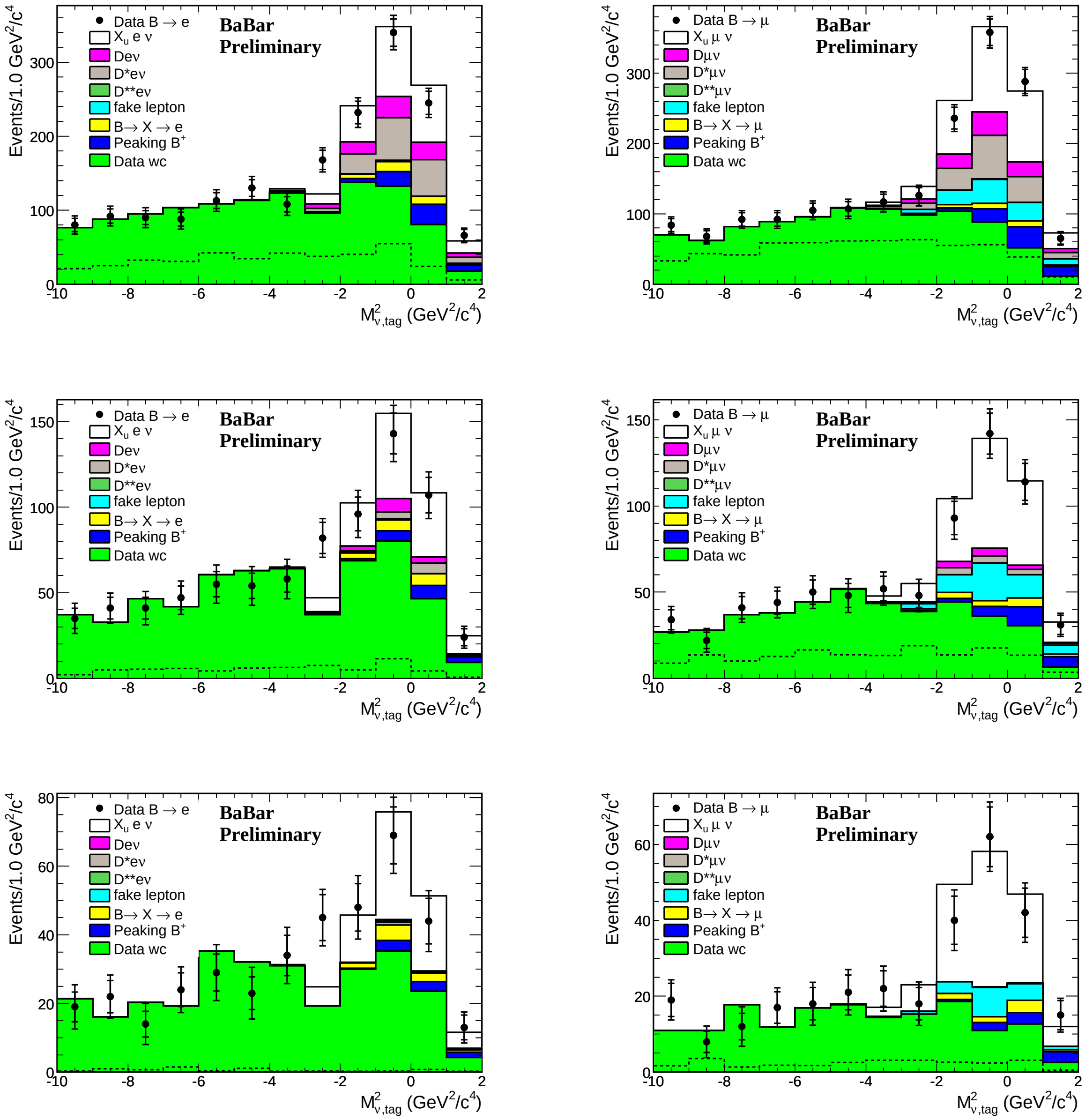

Figure 2: $M^2_{\nu,tag}$ distribution for $2.2 < P_\ell < 2.6\,\mathrm{GeV}/c$(top), $2.3 < P_\ell < 2.6\,\mathrm{GeV}/c$ (center) and $2.4 < P_\ell < 2.6\,\mathrm{GeV}/c$ (bottom), for e (left) and μ (right). The signal component from simulation and the wrong-charge sample have been rescaled according to the fit results. The inner error bars are the statistical error from the right-charge sample only while the larger error bars include also the statistical errors of the wrong-charge sample and of the various peaking components described by the simulation. The distribution of the combinatorial $B\overline{B}$ background, (dashed histogram) is overlaid to illustrate the contributions from continuum and non-peaking $B\overline{B}$ backgrounds as expected from simulation.

Table 1: Event yields for e and μ with $M^2_{\nu,tag} > -3$ GeV^2/c^4, for three intervals of lepton momentum. Only the statistical errors are reported. $\Delta\mathcal{B}^0$ is the partial branching fraction in units of 10^{-4}, separately for e and μ. The last row shows the final result obtained from their averages accounting for the systematic errors.

ΔP_ℓ	$2.2-2.6$ GeV/c		$2.3-2.6$ GeV/c		$2.4-2.6$ GeV/c	
	e	μ	e	μ	e	μ
Data	1051	1073	452	428	219	177
$P(\chi^2)$	0.06	0.87	0.10	0.93	0.13	0.78
N^{comb}	463±21	352±17	242±17	156±12	112±11	60±7
B^-_{tag}	61.1±4.4	69.3±4.5	18.0±2.4	25.2±2.7	7.8±1.6	8.5±1.5
Cascade	32.7±3.5	23.5±2.7	17.6±2.7	14.3±2.1	9.1±2.1	7.0±1.5
Fake ℓ	3.2±1.4	95.0±5.6	1.7±1.0	53.7±4.2	1.3±0.9	16.7±2.3
$D^{**}\ell\nu$	0.5±0.4	0.7±0.5	0	0	0	0
$D^*\ell\nu$	151.5±6.9	152.1±6.8	12.7±1.9	12.9±2.0	1.0±0.6	0.2±0.2
$D\ell\nu$	77.5±4.9	83.0±5.1	14.8±2.1	11.6±1.8	0.6±0.5	0.2±0.2
$X_u\ell\nu$	250.9±51.8	339.4±50.2	131.1±36.9	172.0±32.2	77.4±26.6	96.9±21.8
$\varepsilon(\Delta P_\ell)$ %	35.9±1.2	28.5±1.2	37.6±1.7	32.0±1.5	39.0±2.5	30.3±2.1
$1+\delta_{rad}$	1.0903	1.0228	1.1026	1.0302	1.1195	1.0379
$\Delta\mathcal{B}^0$	2.11±0.44	3.40±0.50	1.07±0.30	1.53±0.29	0.61±0.21	0.92±0.21
Average $\Delta\mathcal{B}^0$	2.62±0.33±0.16		1.30±0.21±0.07		0.76±0.15±0.05	

and δ_{rad} is a factor that corrects for the impact of final state radiation, primarily on the lepton spectrum. We use the simulation to compute the efficiency of the selection $\varepsilon(\Delta P_\ell)$. We estimate δ_{rad} by comparing the spectra generated with and without photon radiation, simulated with PHOTOS [17].

The final result for the partial branching fraction for each interval ΔP_ℓ, obtained by averaging the partial branching fractions for e and μ, are reported in Table 1 (last row). The average is computed with the COMBOS package [18] and accounts for the correlations between systematic uncertainties, which are described in the next section.

5 SYSTEMATIC STUDIES

We compute the total systematic error by adding in quadrature all uncertainties induced by background subtraction and efficiency calculation.

We vary the fraction of B^+ peaking background by ±10%, corresponding to the uncertainty we assign to the isospin symmetry relation (see above).

To estimate the systematic error associated with the uncertainty in the average energies of the colliding beams, we change in our simulation the beam energy by 1.5 MeV and study the changes in the shape of the lepton momentum spectra for the signal events.

We vary the efficiencies for e and μ identification within their uncertainties by ±1.4% and ±2.2% respectively.

The uncertainty on track reconstruction (±0.5% per track) directly affects the lepton track reconstruction. In addition, the uncertainties in the reconstruction of the remaining charged tracks and the photons (±1.8% per shower) introduce an error on the event selection efficiency, because they affect some of the variables used to subtract the continuum: N_{track}, p_{miss}, M_{tot} and the

Table 2: Breakdown of all the sources of error (expressed in %). The first row shows the confidence level of the e-μ averaged result, including all systematic uncertainties.

ΔP_ℓ lepton momentum range	2.2-2.6	2.3-2.6	2.4-2.6
Statistical	12.6	16.1	19.3
Systematics	6.1	5.	6.4
Monte Carlo statistics	2.8	3.4	5.0
Peaking B^+	2.5	1.1	1.2
N_B^0	1.3	1.3	1.3
B movement	0.4	1.0	1.5
Event Selection	1.0	1.1	1.9
PID	1.3	1.5	1.4
Radiation	1.1	1.2	1.3
$J/\psi, \psi'$ bkg	0.5	0.2	0.2
Fake lepton	2.3	2.9	1.7
$B \to D\ell\nu$	1.9	0.0	0.0
$B \to D^*\ell\nu$	2.4	0.5	0.0
$B \to D^{**}\ell\nu$	0.1	0.0	0.0
X_u composition	0.7	0.4	0.4
$s\bar{s}$ pair production	1.2	0.5	0.3

aplanarity A.

Misidentification rates are measured with data control samples of π, K and p from K_s, D^0, and Λ decays. They are less than 0.1% for electrons and about 2% for muons. The contribution of the fake electrons to the peaking background is negligible, whereas there is a sizeable contamination from fake muons (see Tab.1). We vary the electron fake rate by $\pm 50\%$.The uncertainty on the muon fake rate is due the to systematic error in the measurement of the mis-identification probabilities in data and simulation; and in the differences in the production rate of high-momentum pions in data and in simulation. The first effect is estimated by comparing the data-simulation correction of two different hadron control samples: $D^* \to \pi_{soft}(K\pi)$ and $\tau \to 3$ *prongs*. To estimate the effect of pion production, we compare in data and Monte Carlo the number of candidate pion tracks that fail both a loose muon and electron selection. The total uncertainty on the muon fake rate is 15%, that is obtained by adding in quadrature the two uncertainties described above.

A sizeable source of background is due to $B \to J/\psi(\to \ell\ell)X$ decays that are not identified because one of the leptons is undetected. We vary their number by the error on the inclusive branching fraction for $B \to J/\psi X$ decays ($\pm 3\%$)[21]. The contribution from $B \to \psi'(\to \ell\ell)X$ is negligible.

We model $B \to D\ell\nu$ and $B \to D^*\ell\nu$ decays with a parametrization of their form factors inspired by the Heavy Quark Effective Theory [19]. We use the latest measurements of the form-factor parameters [20] and vary each parameter by its error.

We vary the values of the branching fractions for $\mathcal{B}(B \to D^*\ell\nu)$ and $\mathcal{B}(B \to D\ell\nu)$ by their errors; we assume $\pm 100\%$ systematic uncertainty on $\mathcal{B}(B \to D^{**}\ \ell\nu)$. The amount of the remaining backgrounds has negligible effect on the fit result.

We study the sensitivity of the selection efficiency to the composition of the signal. We vary the branching fractions of the various exclusive $B^0 \to X_u\ell\nu$ decays channels within their uncertainties:

$\pm 12\%$ for $B^0 \to \pi\ell\nu$, $\pm 22\%$ for $B^0 \to \rho\ell\nu$ and $\pm 14\%$ for inclusive $B^0 \to X_u\ell\nu$. The efficiency varies by less than one percent, being mostly sensitive to $B^0 \to \rho\ell\nu$ decays.

The kaon veto also affects the signal efficiency due to $s\bar{s}$ pair production (also "$s\bar{s}$ popping") in semileptonic charmless B decays. If we vary the kaon production by $\pm 30\%$, the result changes by 1.3%. Table 2 shows the relative systematic errors induced by all the sources described above.

6 RESULTS AND CONCLUSIONS

We have measured the partial branching fraction for charmless semileptonic B^0 decays for several overlapping intervals in the lepton momentum. The results are listed in Table 3. For the momentum range from 2.3 to 2.6 GeV/c we obtain $\Delta\mathcal{B}(B^0 \to X_u\ell\nu) = (1.30 \pm 0.21 \pm 0.07) \times 10^{-4}$. This first measurement for neutral B mesons can be used to test isospin invariance, using the ratio

$$R^{+/0} = \frac{\Delta\Gamma^+}{\Delta\Gamma^0} = \frac{\tau^0}{\tau^+} \cdot \frac{\Delta\mathcal{B}(B^+ \to X_u\ell\nu)}{\Delta\mathcal{B}(B^0 \to X_u\ell\nu)}, \tag{3}$$

where $\tau^+/\tau^0 = 1.071 \pm 0.009$ [21] is the ratio of the lifetimes for B^+ and B^0. Since no measurement of the partial decay rate is available for charged B mesons, we use the earlier untagged BABAR measurement [8] for the sum of charged and neutral B mesons and determine $R^{+/0}$ from the following expression,

$$R^{+/0} = \frac{\tau^0}{\tau^+} \cdot \frac{1}{1 - f_{00}} \cdot \left[\frac{\Delta\mathcal{B}(B)}{\Delta\mathcal{B}(B^0)} - f_{00}\right], \tag{4}$$

where $f_{00} = 0.494 \pm 0.008$ [21] is the $\Upsilon(4S) \to B^0\overline{B}^0$ branching fraction.

The overlap of the data sample of the two BABAR measurements is negligible. We consider the systematic errors due to PID efficiency and fake rates, charged particle tracking, ψ background and radiative effect fully correlated. For the interval 2.3 to 2.6 GeV/c, we obtain $R^{+/0} = 1.18 \pm 0.35 \pm 0.17$, compatible 1.0. We can also express the result in terms of the charge asymmetry,

$$A^{+/0} = \frac{\Delta\Gamma^+ - \Delta\Gamma^0}{\Delta\Gamma^+ + \Delta\Gamma^0} = \frac{R^{+/0} - 1}{R^{+/0} + 1}, \tag{5}$$

and obtain, for the same momentum interval, $A^{+/0} = 0.08 \pm 0.15 \pm 0.08$, compatible with zero. Thus, with the presently available data sample, there is no evidence for a difference in partial decay rates between B^0 and B^+ at the high end of the lepton momentum spectrum, where we would expect the impact of weak annihilation in B^+ decays. We set an upper limit on the absolute value of the charge asymmetry to $|A^{+/0}| < 0.35$ at 90% confidence limits (C.L.). If we define $\Delta\Gamma_{WA} = \Delta\Gamma^+ - \Delta\Gamma^0$ the contribution of the weak annihilation, we write the relation

Table 3: Results of this analysis (3^{rd} column), compared to the untagged BABAR result (2^{nd}) [8]. The result for $R^{+/0}$ and $A^{+/0}$ are also reported.

ΔP_ℓ	$\Delta\mathcal{B}(B) \cdot 10^4$[8]	$\Delta\mathcal{B}(B^0) \cdot 10^4$	$R^{+/0}$	$A^{+/0}$
$2.2 - 2.6$ GeV/c	2.31±0.10±0.18	2.62±0.33±0.16	0.71±0.22±0.16	-0.17±0.15±0.11
$2.3 - 2.6$ GeV/c	1.46±0.06±0.10	1.30±0.21±0.07	1.18±0.35±0.17	0.08±0.15±0.08
$2.4 - 2.6$ GeV/c	0.75±0.04±0.06	0.76±0.15±0.05	0.91±0.37±0.18	-0.05±0.20±0.10

$$A^{+/0} = \frac{\Delta\Gamma^{+} - \Delta\Gamma^{0}}{\Delta\Gamma^{+} + \Delta\Gamma^{0}} = \frac{f_{WA}(\Delta p)\Gamma_{WA}}{2 \cdot f_{u}(\Delta p)\Gamma_{u}}, \tag{6}$$

where $f_{WA}(\Delta P_\ell)$ refers to the fraction of the weak annihilation rate contributing in the momentum interval ΔP_ℓ, $f_u(\Delta p_\ell)$ is the fraction of lepton spectrum in the same momentum interval ΔP_ℓ and Γ_u is the total $B \to X_u \ell \nu$ decays width. We can write the relative impact of the Γ_{WA} on the $B \to X_u \ell \nu_\ell$ as

$$\frac{|\Gamma_{WA}|}{\Gamma_u} = \frac{2 \cdot f_u(\Delta P_\ell)}{f_{WA}(\Delta P_\ell)} \cdot A^{+/0}. \tag{7}$$

Using $f_u(2.3 - 2.6) \approx 5.5\%$ [22], we can place, depending on f_{WA}, a limit of

$$\frac{|\Gamma_{WA}|}{\Gamma_u} < \frac{3.8\ \%}{f_{WA}(2.3 - 2.6)}, \qquad \text{at 90\% C.L..} \tag{8}$$

This results is also consistent with a limit set by the CLEO Collaboration [23].

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